2025 In-Time Information Integration System (I^3S)

A Research Paper
Presented To

Air Force ***2025***

by

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2025 is a study designed to comply with a directive from the chief of staff of the Air Force to examine the concepts, capabilities, and technologies the United States will require to remain the dominant air and space force in the future. Presented on 17 June 1996, this report was produced in the Department of Defense school environment of academic freedom and in the interest of advancing concepts related to national defense. The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

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Executive Summary

This white paper describes the structure needed to integrate all sources of data and information with people, knowledge, skills and wisdom in order to fuel a concept called top-sight vision. Top-sight vision occurs when diverse players from different military services, and different political, cultural, and economic systems transcend personal and organizational imperatives and coalesce their vast information, knowledge, wisdom, and experience in order to achieve "community" objectives or goals that are of greater value than the sum of the individual parts. The amalgamation of trusting relationships provides insightful, holistic views of events, issues, activities, and/or situations. Since these relationships afford the opportunity to address all perspectives and points of view, the element of surprise is reduced and top-sight vision is achieved.

The objective is to capture the truth, learn an adversary's mind and methodologies, anticipate responses, reactions, and identify intentions in time to plan and initiate preemptive strategies, employ countermeasures, formulate new strategies, and/or launch a decisive attack. The key is to seek and hold the high ground, whether on the battlefield, the global stage, or a combination of the two. In the alternate worlds of 2025, unilateral military actions against other nations will likely exist only in history books. Coalition decisions and warfare will be the normal mode of operations. Meeting these new challenges in 2025 demands new skills and specialized technologies.

Telecommunications now link nearly all areas of the world in which the economies already are dynamically interconnected. This expanding web of interdependence will continue to encompass political, diplomatic, and military relationships at levels unprecedented in history. To obtain maximum effectiveness, top-sight vision demands the world's best communication systems, "community" cooperation, a network of highly intelligent computers, and superbly responsive collection systems that have access to needed information, from open sources to highly sensitive intelligence.

All authorized users will have access to vital information when they need it, where they need it, and how they need it. The combination of data, access, and system connectivity is referred to as the I^3S. The system will rely on an advanced architecture of communication systems, computer networks, and computer subsystems. It will employ AI, neural nets, and fuzzy logic to transform data into information, identify knowledge gaps, determine where needed information resides, cue collection assets, select alternate communication paths, and operate push-pull dissemination and access tools.

To support this system, a series of intelligent microprocessor "brains" working in an optical medium must be perfected, while new mediums for data transfer will have to be validated to minimize interference and maximize security. The intelligent microprocessor brains will be embedded throughout a distributed global architecture. These brains are needed to distribute processing, reduce single-point failures, maximize data integration, reduce timeliness, assure information flow and data access, improve subsystem responsiveness, and employ alternate communication paths.

The brain processors are all-knowing, all-sensing with regard to changes in the target environment, system status, sensor status, access, information demands, user needs,

people skills and expertise, as well as detecting sophisticated hackers violating the system. While much of the collected data would simply be archived and used to update historical trends and patterns, the I^3S AI software would detect and assess target deviations, automatically alert appropriate users, and, as necessary, cue collection assets. This process ensures early recognition of enemy activities and intentions, while enhancing opportunities for survivability. During war, for example, new target locations or weapons parameters could be directly programmed into weapon systems of the United States and allied forces in time to effect a kill.

Another key attribute of this global information net is its commercial value. This system and its subsystems would clearly benefit all types of people and organizations. Imagine an airman in a battle environment or a plumber tapping into the net through a two-way wrist communicator to check the status of required spares or the next task. On the down side, cross-sector sharing demands that new techniques be designed for multilevel security protections. On the positive side, it means cost-sharing, which is vital for effective and efficient development and deployment.

This paper describes a multifaceted system that gives the US the high ground through rapid recognition of "hot spots," insightful views of events from global or local perspectives, and improved decision processes. It also stresses the team approach across all elements that impact international relationships, warfare, and the decisions that surround warfare. The intent is to use all means possible to win all battles and to assure the superpower status of the United States well into the twenty-first century.

In detailing requirements, this paper primarily focuses on the technological tools that are needed to create the I^3S. Although the need for cultural and organizational

changes are recognized, this paper does not address these issues in detail. Indeed, both topics are subjects for separate papers.

Chapter 1

Introduction

> *Any military—like any company or corporation--has to perform at least four key functions with respect to knowledge. It must acquire, process, distribute, and protect information, while selectively denying or distributing it to its adversaries and/or allies.*
>
> —Alvin and Heidi Toffler

Ensuring the superior defense of this great nation in a rapidly changing and diverse world requires new ways of doing business, new partnerships, vision, action, leadership, and advanced technologies. As we approach 2025, the increasingly complex and interconnected world demands a greater quest for knowledge and wisdom--a quest that is unprecedented in the history of mankind. Simply seeking wisdom will not sufficiently deal with the evolving issues that will confront world leaders in 2025. Integrating knowledge and collectively sharing wisdom, ideas, and concepts will significantly increase the opportunities for success. This cooperative and interactive process will become a prerequisite for superior leadership and decisive actions.

Never before in the history of the world has one nation emerged with the overwhelming power, strength, will, and leadership that the United States has. This singular superpower status calls for "top-sight"[1] (See Appendix) vision, a concept that

integrates diverse players from different backgrounds who transcend personal and organizational imperatives and coalesce their vast resources of information, knowledge, wisdom, and experience in order to achieve "community" objectives or goals. Top-sight vision can only emerge from collective wisdom that is built upon a diverse information network of integrated resources, open minds, collaborative analyses, and advanced communications and computer support systems.

Critical to future decision makers will be the strength of character and courage to acquire top-sight vision through openly sharing and exchanging views, information, knowledge, and wisdom, as well as personal experiences and instincts. A lightning-fast, on-demand, world-class information integration system will connect all authorized users to a diverse spectrum of data, information, and experts. Such a system would form the cornerstone of global awareness and serve as the prerequisite for information dominance.

Leveraging technology to dominate information, and to put that information where it is needed when it is needed, will be a significant force multiplier. Likewise, gaining complete access to needed information--and validating that information--will limit misinformation, enhance the opportunity for peace, and provide the basis for success in battle and speedy resolutions to crises.

Equally critical to this nation's defense are accurate intelligence, on-time maintenance and logistics support, well-trained military forces and modern weapon systems. These are the essential building blocks that fuel and enhance key competencies for global awareness, global reach, and global power.

Although the world is a dangerous place, the future is indeed uncertain. Weapons proliferation, international crime, and territorial disputes, coupled with the increasing gap

between the "have" and "have not" nations, serve to make the world a far more dangerous place in which to live. The dimension and quality of the decision cycle to foresee and respond to looming crises will be highly dependent on the information that feeds it as well as the interactive and cooperative spirit of the decision makers.

This paper defines the structure that is needed to integrate multiple layers and diverse types of data and information to gain global awareness and achieve top-sight vision. In the world of 2025, technologies combined with effective information offer the best opportunity to know the adversary's capabilities and to gain significant insight into intentions and reactions. There is no doubt that the side that best exploits information and gains top-sight vision will achieve the greatest advantage in resolving disputes and winning wars.

Gathering and synthesizing data into information, correlating information, and sharing knowledge call for sophisticated computer systems and advanced telecommunication networks. The systems must employ advanced parallel and distributive processing techniques. They must also employ secure broadband communications to dynamically link systems, collection resources, producers and users. The systems also must be compatible across all users. Both computer systems and telecommunication networks must be highly responsive to human and machine interfaces, innovations, and interventions, and they must automatically learn to adapt to changing needs. All systems must be accessible via interactive voice commands, advanced modems, cellular-type devices, and other as yet unknown technologies that will emerge.

These highly interactive computer systems and communication networks will form the backbone of the I^3S, which is completely decentralized but is highly interactive from

anywhere in the globe, at any time. The flow, exchange, and integration of information, knowledge, wisdom, instincts, and experience are defined in the assessment pyramid (Appendix), which serves as the conceptual model for top-sight vision. This model also is the driver for changing cultural and organizational habits, which are prerequisites for successfully achieving information dominance.

The top-sight model of knowledge and information is designed around the functions of the human brain, a concept which encourages the integration of pragmatic and rational intellectual skills with the instincts and intuitions resulting from algorithmic identifiers and flags based on experience, insight, and knowledge. This system must be supported by seamless processing and data access, AI, secure communications, and computer systems that create a virtual global community where location is transparent, access is commensurate to a user's security level, and information access is supreme.

To reduce research and development costs and shorten cycle times, every effort must be made to acquire commercial, cutting-edge, off-the-shelf equipment and software. The information integration system for 2025 must provide in-time, on-demand, actionable intelligence to authorized users when they need it, where they need it, and in the format they need.

The I^3S this paper proposes must give authorized users dynamic responses to requests for new data from anywhere and at anytime, determine what data already exists, and, automatically cue or alter collection resources to new or changing requirements. At the same time, the system must automatically generate feedback and status reports to users, inform them of actions taken, advise them when data will become available, and inform them of the requirements that cannot be satisfied.

The information revolution is a harbinger of notable changes in the conduct of war. As Martin van Creveld said in *Command in War*, "The history of command can thus be understood in terms of a race between the demand for information and the ability of command systems to meet it." Consequently the United States must make a collective effort to establish the strongest I^3S capability in the world.[2] The revolution in military affairs surrounding information dominance is as important and vital as the advent of steam propulsion, the radio, radar, the tank, or the airplane.

Whether preparing for warfare or diagnosing world events or issues, the need for global awareness has moved the need for information dominance to center stage. In the view of Gen John Shalikashvili, Chairman of the Joint Chiefs of Staff, "The commander who owns the information owns the outcome of the war . . . [m]y challenge is to meet the warrior's quest for information . . . the right information, to the right person, at the right time, in the right place, in the right form to achieve victory for any mission."[3]

> The joint campaign should fully exploit the information differential, that is, the superior access to and ability to effectively employ information on the strategic, operational and tactical situation which advanced US technologies provide our forces.[4]

Notes

1. Model created by the authors.
2. To realize this vision, Command, Control, Communications, and Computer Intelligence (C^4I) systems must be built under a JCS unified strategy. These systems must then be embedded in all forces, ready to execute on demand. Information-based warfare systems must take the information high ground to integrate battlefield information and in turn increase the effects of maneuver and firepower. Properly designed, a system of this nature will be the ultimate force multiplier, with the ability to grow with the situation.

3. J-6 Directorate, Office of the Joint Chiefs of Staff, *C^4I For The Warrior, Global Command and Control Systems, From Concept To Reality* (Washington D.C.: Office of the Joint Chiefs of Staff, 1994), 2.

4. Adm Jeremy M. Boorda, "Leading the Revolution in C^4I," *Joint Force Quarterly*, no. 9 (Autumn 1995): 16.

Chapter 2

The *2025* Challenge

The dynamic and chaotic pace of today's world is not likely to slow down. Indeed, the pace will likely increase. Therefore, understanding and controlling information will be a significant core competency for warfare by the year 2025.

To meet future challenges, we must develop a system of systems that will survive research, development, and acquisition processes in light of a dynamic and changing future. Considering the proposed alternate futures for 2025, I^3 will be essential to decision makers. In some plausible futures, I^3 will be more important than in others, but all such studies agree that information will continue to be power. Consequently, the high ground of the future will be information dominance and global awareness.[1]

Creating thoroughly cooperative working relationships across all military services and the intelligence community is by far the most difficult challenge. Territorial imperatives, different data needs, varying roles and missions, alternate solutions to common problems, and differing visions are gargantuan impediments to success. Overcoming these impediments will require astute leadership, focused vision, and unprecedented cooperation among the services, intelligence institutions, industry, and academe. The areas where institutional inertia must be totally eliminated include information integration

and information dissemination. Data formats, databases, communication paths, and integration tools must be 100 percent compatible; leaders must have zero tolerance for organizational or institutional barriers..

Developing the concepts and means to selectively and rapidly move accurate information across a vast, secure cyberspace, while accurately fusing intelligence, detecting information deception, securing credible knowledge sources, and employing the laws of probability are the technical challenges for the next 30 years.

In addition to creating conceptual and managerial cooperation among disparate sectors within the United States, two specific problems must be tackled: stemming the high cost of developing software and limiting obsolescence that results when technology moves faster than equipment integration.

"Force Modernization is the Blue Print for [today's tenets of] Global Reach and Global Power. Our Strategic Vision remains containment through deterrence."[2] To accomplish this, the Air Force reorganized into Air Combat Command (Global Power) and Air Mobility Command (Global Reach). To realize this vision, the Air Force of the 1990s pressed on with the C-17 as the key short-term solution, developed upgrades in conventional capabilities to meet mid-term requirements, and pursued long-term planning for transatmospheric reusable lift capability to prepare for the future. As we step into the new millennium, and especially as we look to 2025, information dominance becomes the blueprint for success in maintaining global peace. Logically, an effective I^3S transcends the entire spectrum of near- to long-term decision-making requirements.

Top-Sight Vision $\Rightarrow$ Information Dominance and Security

The top-sight pyramid model (Appendix) was selected because the broadest portion of the pyramid (the base) represents the repository of all available data, while the top segments represent the refined components of knowledge and wisdom. All segments of the pyramid are interactive, and these interactions take place in both horizontal and vertical dimensions. For example, synthesized data flows upward to fuel new knowledge and wisdom, which then refines or defines new needs statements that flow downward and drive the gathering of new data. Each face of the multi-sided pyramid represents a different actor or sets of actors (i.e., military users and planners, intelligence producers, policy makers, academicians, foreign partners or advisors, historians, scientists, economists, etc.). Players change issues as events or needs warrant. The process is highly dynamic.

On the horizontal plane, data, information, knowledge, and wisdom, combined with instincts and experience, are freely shared and exchanged in a virtual and highly interactive process. Information sharing works in any and all directions—laterally or vertically—and is applicable at all levels of an organizational, from the lowest level to the most senior levels. It is the integration and cooperation of the various levels and dimensions that add the value to the top-sight model.

The bottom two layers of the pyramid—data and information—are heavily reliant on machine processing and interfacing technologies and generally answer the basic intelligence questions of *who*, *what*, *where*, or *when.* Patterns of activities and trends also emerge from these levels. These are the levels where other sensors can be cued and

interested parties alerted to ongoing activities and changes in the environment. As this information scales the structure of the pyramid and moves into the upper two layers (knowledge and wisdom), the human-to-human and human-machine interfaces become vitally important, as actors and machines work interactively to answer the *how, why,* and *what if* questions.

To make this highly dynamic and responsive model operate effectively, vast computer systems and telecommunication networks must support the cross-organizational integration of players and databases and provide those players with the tools to fully exchange data and discuss specific events, issues, or needs. The multidimensional aspects of the model forms the basis for cohesive, integrated, and validated knowledge, leading to information dominance and global awareness. Achieving global awareness is the ultimate top-sight vision (Appendix).

Dominance of the information spectrum is required to maintain our national security. Failure to maintain or exploit this dominance will have precisely the opposite effect. Decision makers must have this top-sight vision in order to be able to make the necessary choices in crises and non-crisis situations. In 2025 global events will demand astute decisiveness. Knowing what is transpiring, and having on-demand access to quality data, knowledge, and expertise, will provide a tremendous advantage for effectively maintaining security--a prerequisite for success.

More importantly, having others know that we can know and respond to what is occurring creates a powerful deterrent to hostile activities throughout the world. Such deterrent capability adds to the value of the knowledge itself. Information dominance can create a presence which, in many cases, may substitute for forward deployments of

military forces. For example, instead of sending a carrier air wing into the South China Sea to show the flag in response to an impending crisis, the President could contact various world leaders and attempt to employ the vast knowledge of multiple players. This would allow the surrounding countries to intervene and possibly stop a crisis without the deployment of United States forces. Thus, information dominance could diminish the logistical problems of transportation and sustainment while reducing the risk to American lives. Should conflict become a reality, the in-time information integration system and the top-sight model would provide powerful tools to engage the adversary's forces; anticipate their actions, reactions and intentions; respond decisively; and maneuver and outwit their leaders.

The quantity and quality of information that can be gained through the integration process will enhance our national capabilities--commercially as well as militarily. While many consider space to be the ultimate high ground, information dominance--the ability tot see the other side of the hill--is truly the ultimate high ground. Information dominance is the only vantage point from which to attain top-sight vision. This information dominance will ensure US security well into the twenty-first century.[3]

Notes

1. USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century,* summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 57.
2. Gen Ronald Fogleman, Chief of Staff, US Air Force, address to the 2025 participants, Air University, Maxwell AFB, Ala., 13 February 1996.
3. Adm William A. Owens, "Four Revolutions In Military Thinking," *The Officer* (August 1995), 29-32.

Chapter 3

The In-Time Information Integration System (I^3S)

With interoperability and modifications to current technologies taking us into the year 2000, it is imperative that we focus on new technologies for information dominance in 2025. If we are going to give our warriors a "fused, real-time, true representation of the warrior's battlespace—an ability to order, respond, and coordinate horizontally and vertically to the degree necessary to prosecute his mission in that battle space,"[1] --we must develop a significantly faster and more capable system for 2025. This system must be capable of much more than simply providing a warrior with the battlespace picture. This system must be able to take in all possible data and make algorithmic decisions concerning that data. It must be able to provide our decision makers with a vision into the enemy's observe, orient, decide and Act (OODA) loop.[2]

The goal of the I^3S is to dominate the information battlespace by getting the right information to the right place at the right time. With this, our military will become an information-driven force that relies upon global situational awareness to effectively plan and execute complex missions with minimal risks. Civilian and commercial applications are also envisioned and discussed later in this paper. Crucial to this system is the ability to process raw bits of data, from collection sensors or existing databases, into information

which can be displayed to a human interface and transformed into valuable knowledge, which when integrated with human experience, yields an appropriate decision and/or action.

The vast amounts of data from today's collectors have already produced more information than human analysts are capable of evaluating. Data production from collection sensors in the future will make the problem worse. The increased operations tempo of the future will increase the need for automated integration of information and the requirement for an I^3S.

At the heart of this system is an intelligent microprocessor or a computer with a brain (fig. 3-1). This device enables the system to perform automated, intelligent processing on vast amounts of data from all sources to ensure that the right information gets to the right place at the right time. This is the 2025 evolution of artificial intelligence, neural nets, and fuzzy logic.

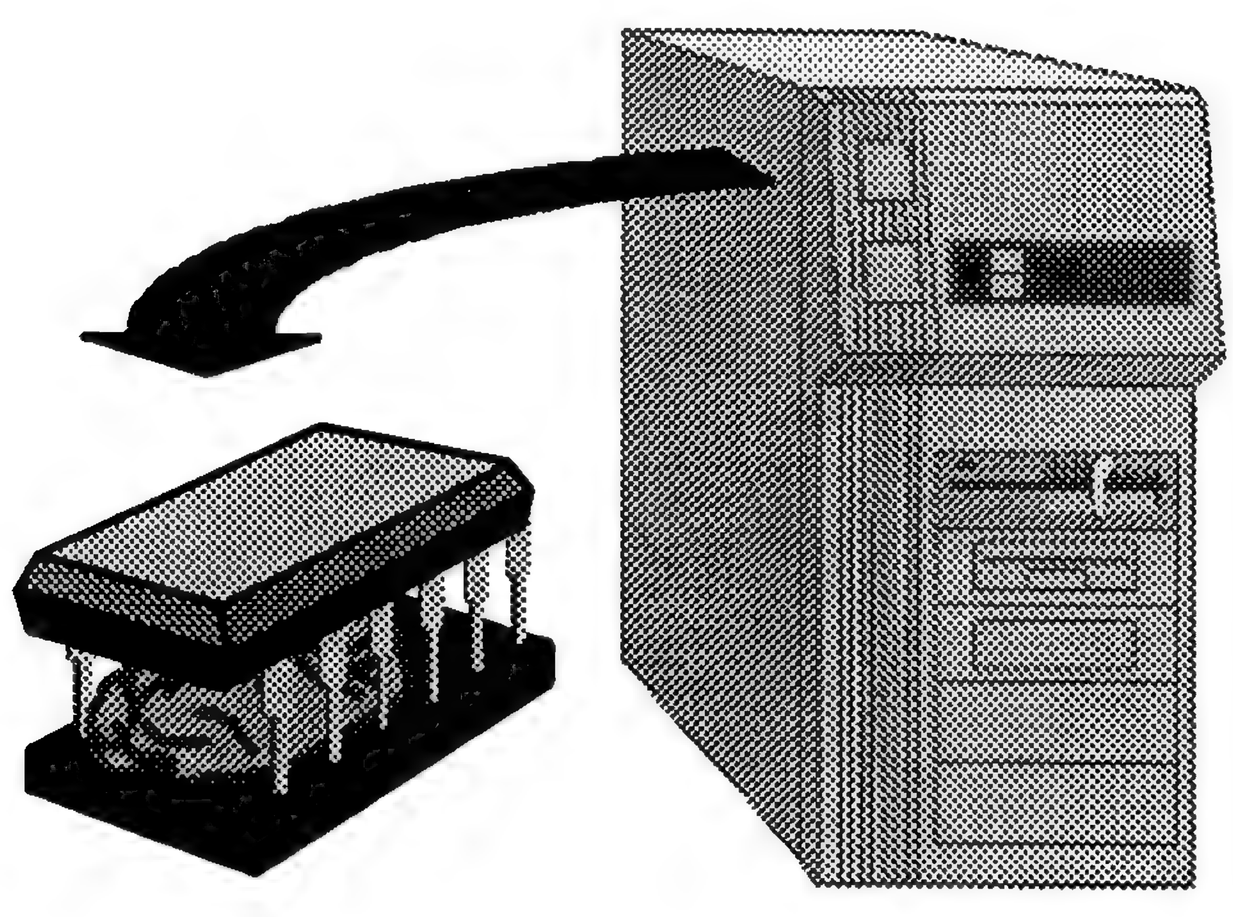


Figure 3-1. Intelligent Microprocessor "The Brain"

This intelligent processor has the ability to recognize a particular user's information needs and to automatically perform the necessary integration of the appropriate data to

produce the desired information product. The information contained in this product depends upon the needs of the requesting user. The user may also provide feedback to the intelligent processor to customize or tailor an information product in response to specific needs or situations.

The first function of the intelligent processor is to analyze the needs of the user. It may either identify the user and default to predetermined request parameters or respond to specific user tasking requests. The processor's brain also associates an appropriate classification level and processing priority with a particular user. Once the analysis of the user's needs is completed, the system brain determines what data it requires to complete the tasking. Identification of data requirements automatically triggers brain neurons to perform a network data search. This is where the intelligent processor linked to a specific user now interacts with other intelligent processor nodes linked through a distributed architecture (fig. 3-2). Through this distributed architecture, the processor has direct access to raw (real-time) and/or pre-processed (near-real-time) data from collection assets as well as worldwide archival databases.

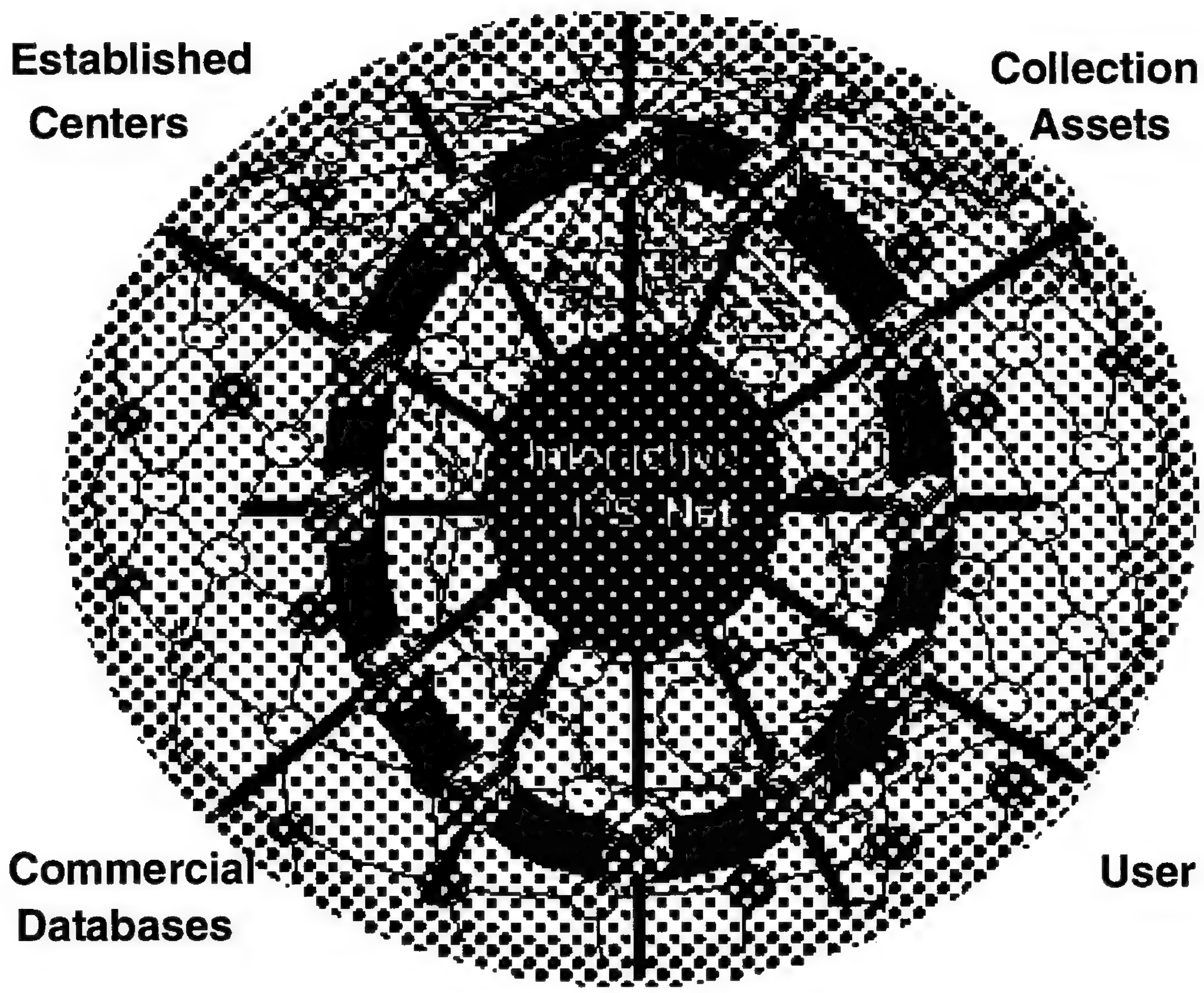


Figure 3-2. Distributed Architecture of Intelligent Processor Nodes

The user in figure 3-2 may represent anyone from a single infantry soldier to the National Command Authority (NCA), including civil and commercial users. Collection assets in figure 3-2 represent all sources of data (e.g., imagery intelligence [IMINT], signals intelligence [SIGINT], measurement and signature intelligence [MASINT], human resource intelligence [HUMINT], early warning [EW]) from any land, sea, air, or space platform. The established centers referred to in Figure 3-2 represent databases and/or processed information available from the Department of Defense and national agencies (e.g.: Central Intelligence Agency [CIA], Defense Intelligence Agency [DIA], National Security Agency [NSA], Defense Mapping Agency [DMA], National Photographic

Interpretation Center [NPIC], SPACECOM) or whatever they have become in 2025. Commercial collection systems data, such as multispectral imagery from LANDSAT and SPOT, would be found in the commercial databases along with future commercial systems data, including data other than imagery. Information from Lloyds of London, for example, may provide valuable insight to maritime traffic (i.e., ship registration, point of origin, destination, cargo, etc.). The intelligent processor nodes and their linkages noted above by no means represent a finite set and are limited only by a decision maker's imagination.

As the intelligent processor linked to the user receives data/information from other processor nodes in figure 3-2, the integration process for the user's information package begins. The phrase "data/information" is used above to indicate that the user's processor may receive more than just bits of data over the nodal net. An intelligent processor node connected to an established center may transmit secondary intelligence products created through manual processing and/or human interfaces. Conclusions from experienced human analysts may also be included for integration if required by the user's processor brain.

After the data/information search has completed, the user's processor may sense a requirement for additional or more recent data/information. This will automatically initiate tasking requests to appropriate collection assets through the proper nodal connections. If the processor determines that it has sufficient information to be of value to the user, the processor would forward the integrated information ("as is") to the user along with a status report indicating the additional tasking request and potential package update.

Note that it is not the intent of the intelligent processor brain to replace all human interfaces. Furthermore, it is not envisioned that the processor brain in 2025 will be as good as a human brain in reaching conclusions and/or decisions; it is necessary however, to facilitate the enormous processing and synthesis of data required by the systems of 2025 that will become uncomprehendable to a human brain.

Intelligent processing is not that far away. Today we teach computers what not to look for in the form of change detection software algorithms. Computers quickly scan thousands of frames of images and detect small changes which may represent targets or threats.[3] Neural nets are used to optimize targeting of defense systems where speed is of the essence, allowing computers to complete analyses of multiple threats and multiple defense systems on a time line that is impossible for humans to meet.[4] A computer uses fuzzy logic to analyze elements in the rinse water of a washing machine to determine whether the clothes require further washing, then automatically adjusts the cycle accordingly.[5]

A host of commercial products that perform data fusion for specific purposes and display the resulting information with easy-to-comprehend three-dimensional graphics are available today. Software products such as Autometric Corporation's "Omni" combine with "Talon Vision," an Air Force Tactical Exploitation of National Capabilities Program (TENCAP) product, to perform an admirable job of displaying near-real-time OP-ELINT situational awareness.[6] Unfortunately, their capabilities fall significantly short when processing varying types of data (e.g., raw imagery, processed imagery, radar phase history data, SIGINT, HUMINT) and/or adapting products to the dynamic needs of different users. "Today's fusion systems, whether embedded or built upon open

standards workstation architecture, are primarily custom-built stand-alone software designs built to the unique needs of a particular project or military task."[7] Limited connectivity and access to information databases continue to severely handicap today's systems. The challenge for 2025 is to provide in-time integration of information from all sources with global dissemination to all levels of users.

This is not intended to imply that all processing in 2025 will be or needs to be automated. Storage media will exist to store vast amounts of raw sensor bits that can be retrieved by those having specific needs that require special processing. It is envisioned, however, that this higher form of automated intelligent processing will satisfy the needs of many users while reducing the inevitable information overload to a level of acceptable comprehension.

Current collection systems (fig. 3-3) fall significantly short of maximizing the utility of their products through effective and efficient integration. Different collection systems viewing the same event, or the same collection system viewing an event from a different geometry, result in duplicate reporting with different results. On numerous occasions, this has led to confusion relative to missile launches and surface-to-air threats.[8] The linkage of a user's intelligent processor to the intelligent nodes of collection systems will make time discrimination and geolocation data available for immediate integration of information into a single product with much higher fidelity. The product may become further enhanced through integration of related information from existing databases. For example, two SIGINT collectors may produce two different geolocation error ellipses for a particular threat. Integrating the information from the two collectors can result in a single error ellipse with greater geolocation accuracy. A simultaneous search for data

relative to the area represented by the error ellipse may result in IMINT or HUMINT confirmation to further pinpoint the location. Another benefit from nodal connectivity is the ability to immediately task or cue other collection assets for new data. Updates to previously released integrated information packages would occur as new data are acquired and a higher fidelity product becomes available.

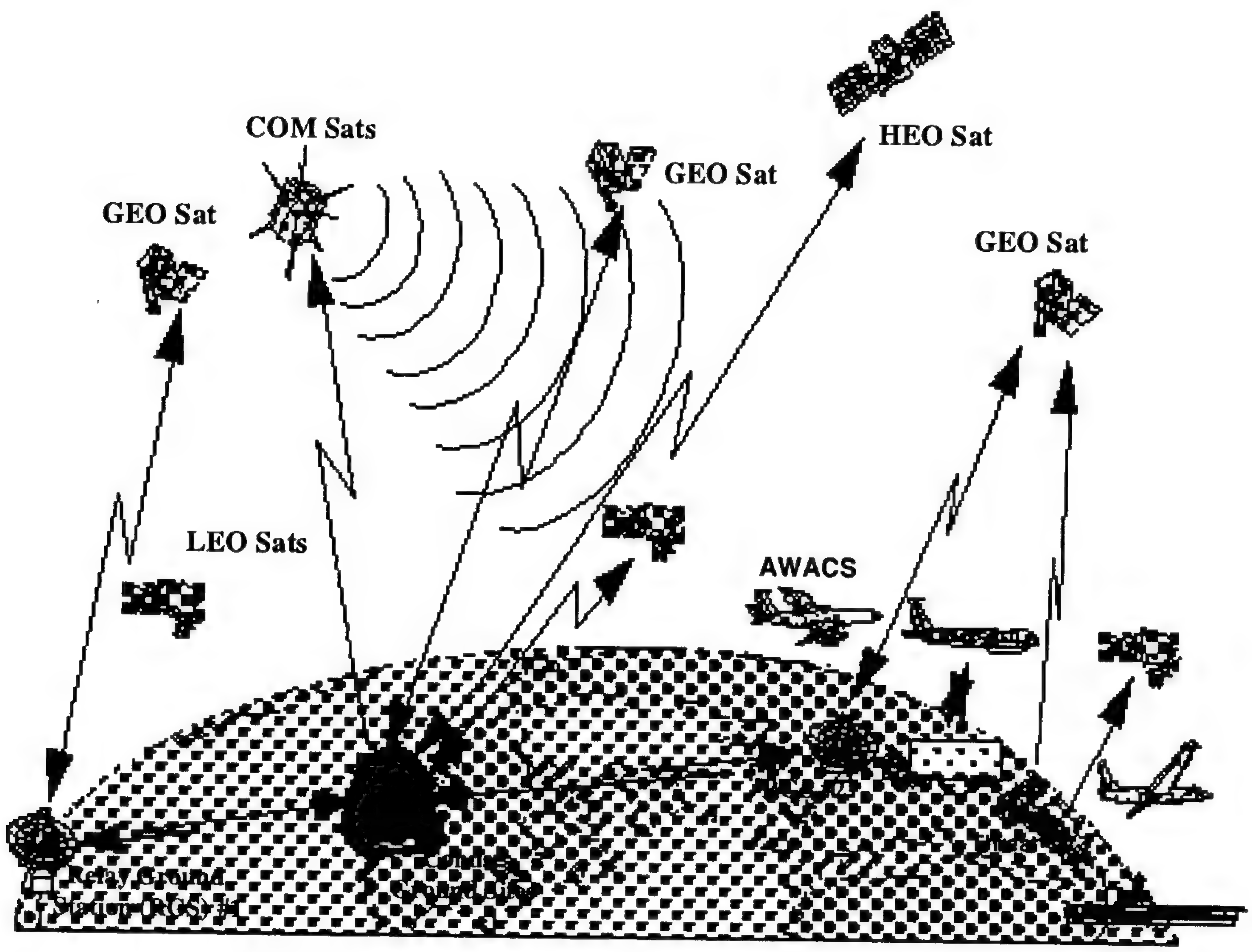


Figure 3-3. Current Collection Systems

Integration of local HUMINT with these information packages could even provide an enemy's intent to a user, instead of simply reporting facts. An intelligent processor could be programmed to recognize certain signals or events as it processes information in an area. When triggered, the processor brain would initiate an information request from

expert analysts, and other HUMINT sources for integration into an information package which will alert the user of a calculated or probable intent of the enemy. This analogy could also work for enemy weapon systems. The intelligent processor would recognize certain events as it processes information, then synthesize when and where an enemy intends to deploy a particular weapon system (rather than simply reporting the weapon's existence).

Connectivity is an instrumental feature of this system. A global grid of multiple intelligent plug-in nodes is envisioned (fig. 3-4). These intelligent processor nodes, either land-, sea-, air-, or space-based, are connected through secure fiber optic trunks and transmitted through atmospheric and/or space mediums only as necessary. The trunk size (i.e., bandwidth) is determined by the expected needs of the user. For example, it is reasonable to assume that a joint task force commander would have more requirements for a larger communication trunk than an infantry soldier in the field. This not only preserves the economy of available bandwidth, but also aids in system security by limiting a potential compromise of information.

Global Plug-In

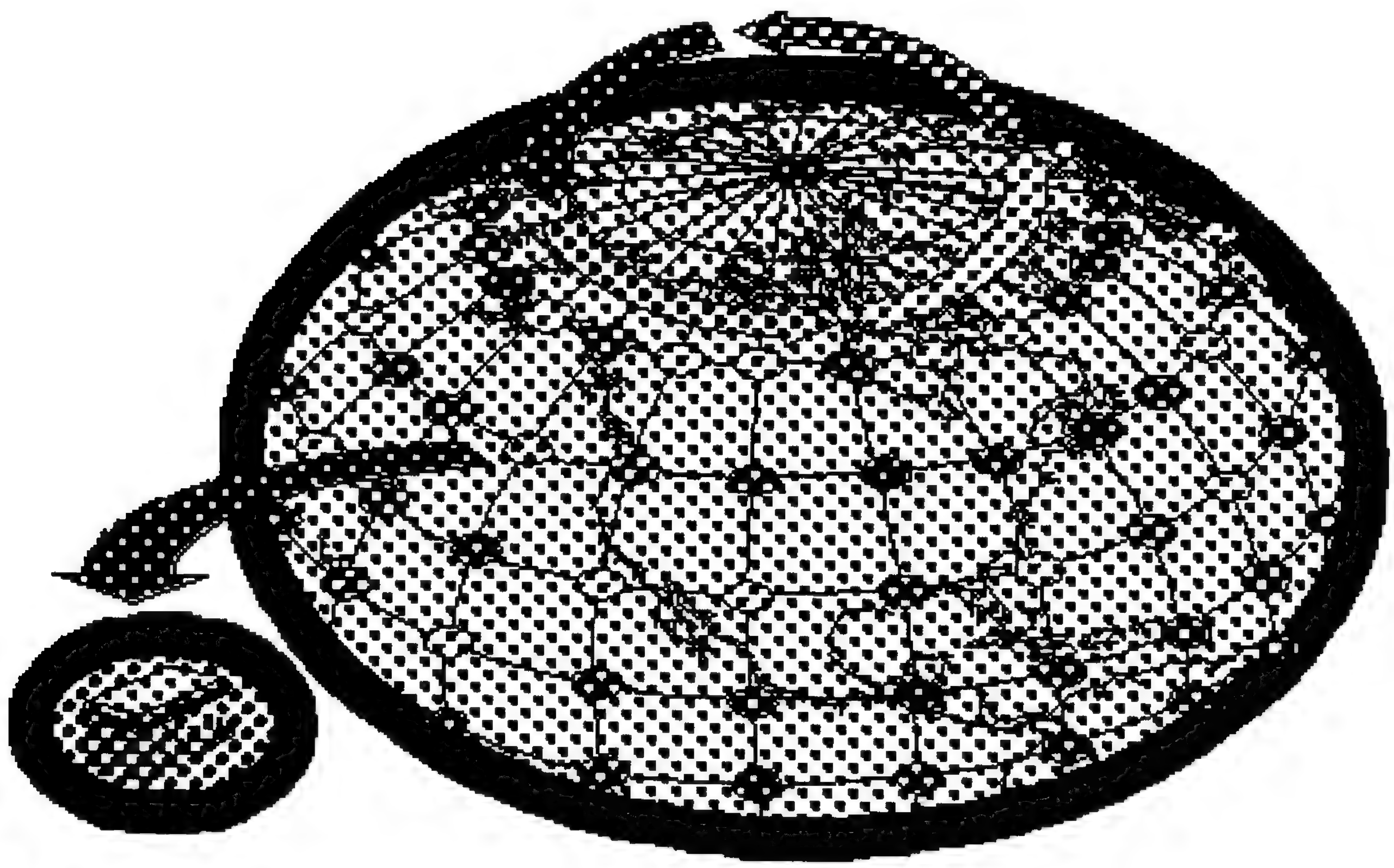


Figure 3-4. Global Grid

The brain of the intelligent processor has the ability to recognize and respond to multiple users on the same node. The brain can associate a specific security level and set information parameters to each user on the node. The information parameters would aid in minimizing the system's overall workload by limiting the processing of certain information to a particular user. In other words, the processor would not respond to an infantry soldier's request for information on deep-strike targeting. This is intelligent processing based on "need-to-know" parameters. The brain would also assign predetermined priorities to each user (which, of course, could be modified at any time by a higher authority).

Even with the speed and complexity of the intelligent processor in 2025, one can envision nodal saturation and temporary shutdowns of specific nodes due to information and user overloads. The global grid connectivity and distributed architecture displayed in figure 3-4 will accommodate instant work-arounds to recover from both unintentional and intentional outages, possibly from enemy attacks. The intelligent processor will also have different processing states. During a crisis or information crunch, for example, the processor brain could resort to a reptilian state, performing simpler processing to produce only that information absolutely necessary for the user. The brain of the processor might also change states and become a channeling node, thus delegating intelligent processing functions to other distributed nodes.

This system would also function as a super global situational awareness tool. By monitoring the processed activities of other intelligent nodes on the distributed network, each node can supply global situational awareness information (figure 3-5). Activities, intentions, data, and information from all users and collection systems are quickly integrated into a visual three-dimensional display to facilitate user comprehension. This global connectivity facilitates the sensor-to-shooter concept of today while supporting a sensor-to-weapon concept for 2025.

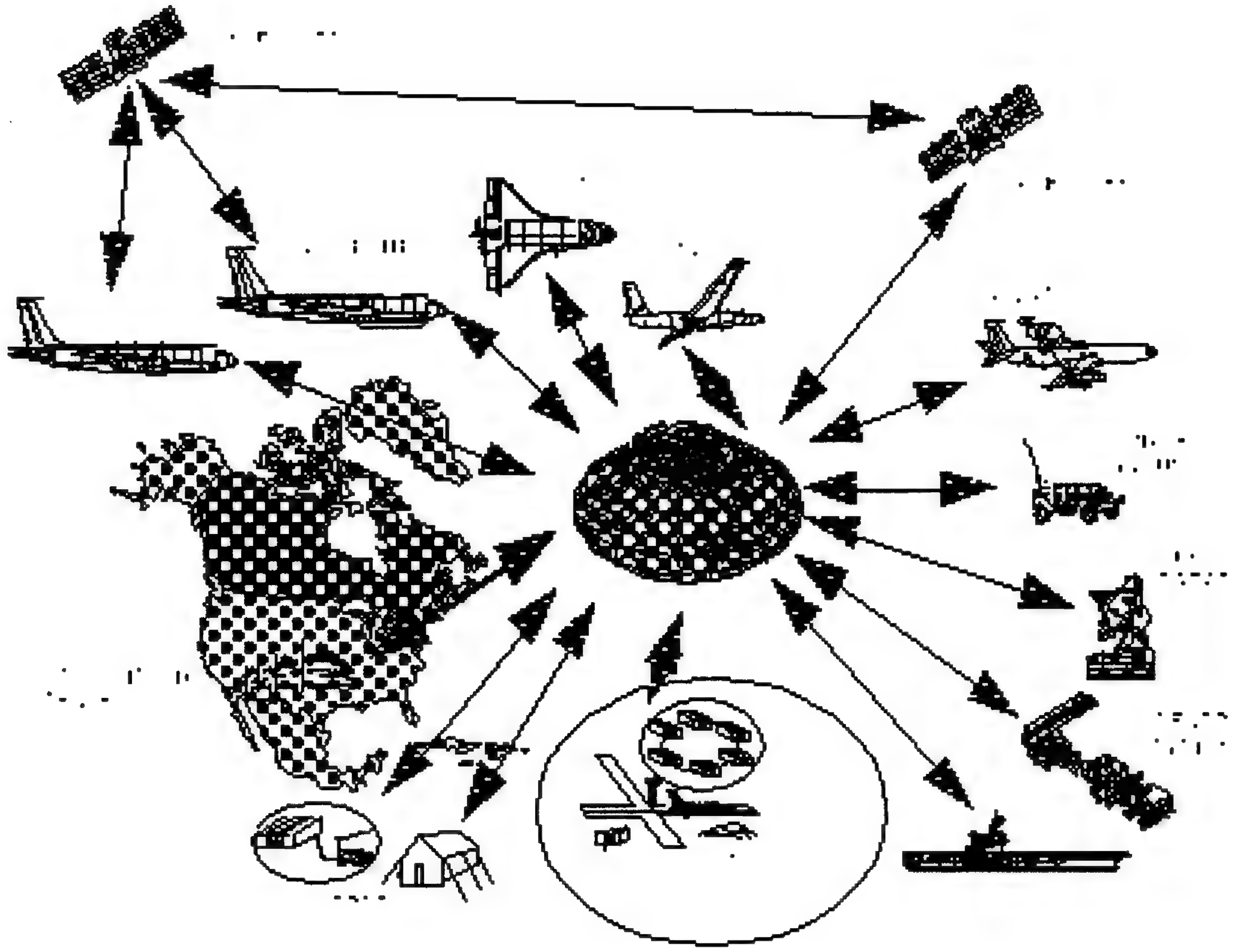


Figure 3-5. Global Connectivity

In figure 3-5, one can envision the system utility and effectiveness of providing all decision makers (e.g., joint task force commanders, ship commanders, air commanders, ground commanders) with continuous global situational awareness by directly linking their intelligent processing nodes. This not only provides them direct access to human analysts and collection assets; it also allows everyone access to the same information, including feedback, to facilitate the coordination of activities among each other.

Display systems would be commensurate with the users needs. An infantry soldier in 2025 will replace his global positioning system (GPS) receiver with a hand-held digital display unit (fig. 3-6). This unit will access an intelligent node and provide much more

than a GPS location. The intelligent processor could highlight potential travel routes for avoiding adverse terrain and/or enemy positions.

Figure 3-6. Hand-Held Access

The system accomplishes this by searching the nodal net for multispectral images of the area; LANDSAT and/or SPOT data would suffice today. The processor brain would process the multispectral images to produce terrain categorization (TERCAT) maps. These TERCATs are then integrated with digital elevation data, possibly from a DMA database, to produce trafficability maps (go, slow go, no go). The processor brain would search the nodal net for the latest information on enemy positions and strengths for the

area of interest, overlay this information on the trafficability maps, determine probable travel routes, and display the results to the user (fig. 3-7). The intelligent node could also perform simpler functions such as confirming target coordinates to artillery soldiers after verifying the latest intelligence information and the commander's intent.

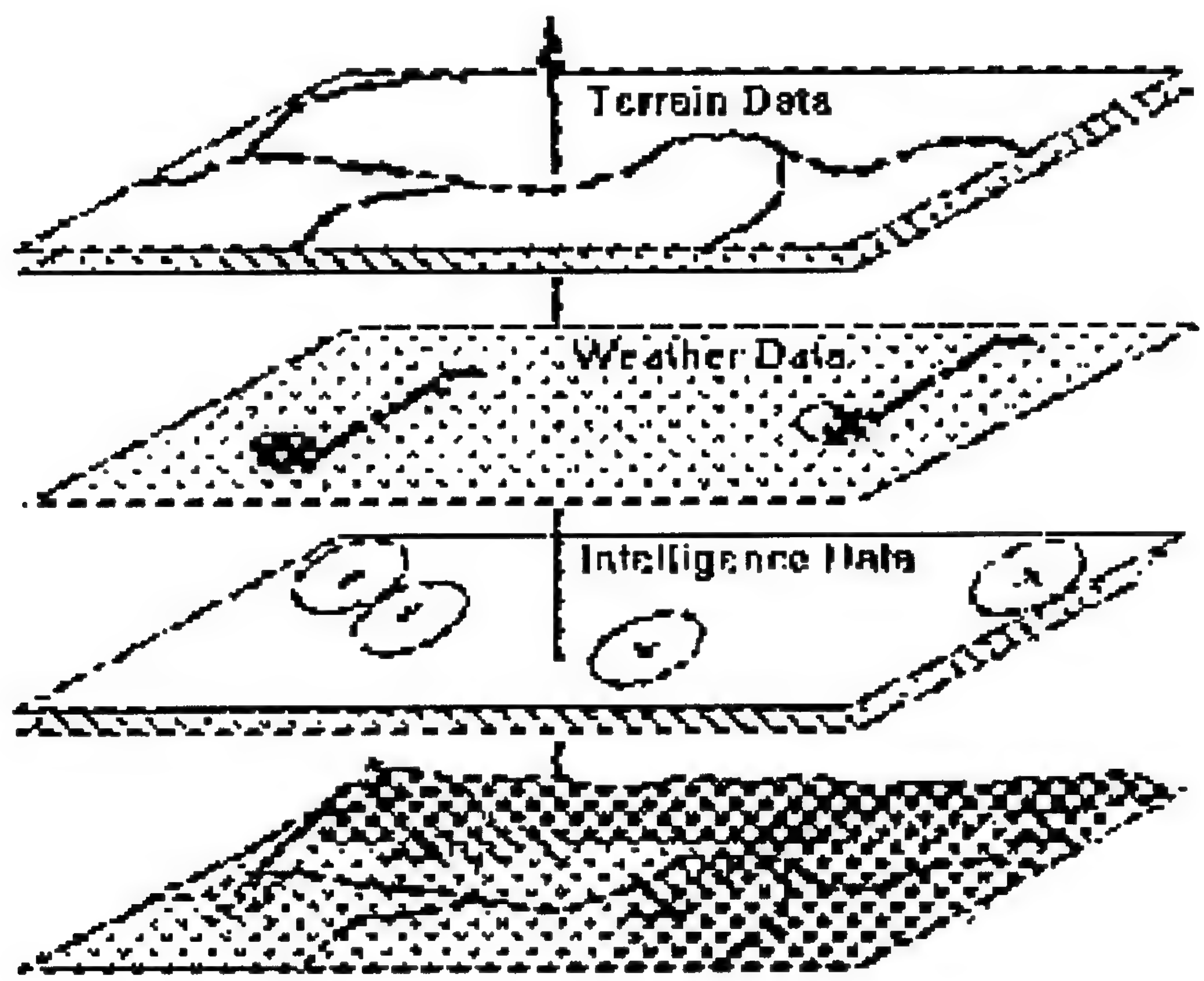
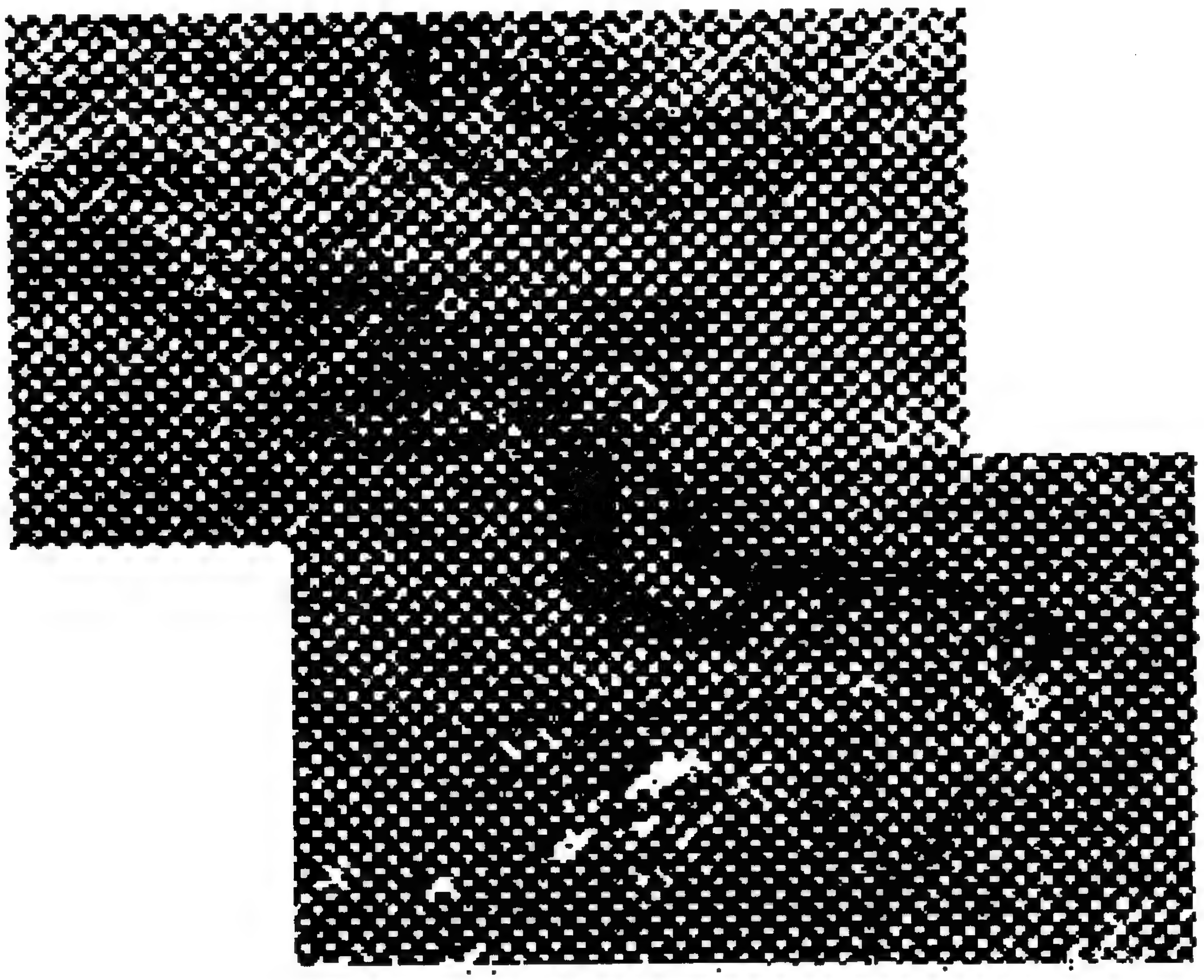


Figure 3-7. Integrating Data Scenes

It is easy to envision a host of civil and commercial applications for a system such as this. For example, a civil engineer who wishes to relocate a town destroyed by flooding may request historical information on the various flood stages of a river in a particular area. The brain of the processing node would identify the user as unclassified and assign a priority to the request. The intelligent processor would in turn prepare an integrated information package for the user. The intelligent processor would most likely use

LANDSAT multispectral data from an EOSAT archive, together with DOD change-detection algorithms, to generate true-color, composite-image maps highlighting the various water levels and affected areas (fig. 3-8).



Images courtesy of the Defense LANDSAT Program Office

Figure 3-8. Mississippi River St. Louis, MO (Before and After Flood)

Although this level of processing exists today, it is not readily available and affordable for general population use. It is envisioned in 2025 that civilian organizations and/or companies who can afford a GPS receiver today could have access to a commercial grid of information. Imagine in 2025 auto clubs planning trip routes and issuing image maps that display current road conditions, construction, detours, and alternate routes (including scenic).

System Security

System security is addressed in several ways. All classified data, and information determined classified as a result of synthesizing unclassified sources, is linked to nodes through encrypted communication trunks. Deciphering occurs at the user terminal and is further controlled through the intelligent nodes' recognition of the user. Recall that the intelligent node limits information passed to various users based on their requirements and/or need-to-know. This becomes important should the enemy should capture a user terminal. Potential compromise of information is limited to the authorization level or access level of the particular user terminal.

The most vulnerable user terminal, most likely a field soldier's hand-held display, also has the lowest authorization or access level. Information compromised at this level would have little value for the enemy. The higher-access-level terminal of a theater commander would be guarded more securely. Any capture at this level would be readily known.

Once the intelligent node recognizes the user terminal as compromised, either through unauthorized information requests or direct (human) reporting, it would alert higher command and await instructions. Higher command may wish to use the captured terminal as a conduit to pass misinformation to the enemy, or it might terminate service to that particular terminal. For more information, see the 2025 Information Warfare paper.

This system meets the demanding challenge for 2025. Not only integrating information on objects with much greater fidelity than is possible today, but also processing information orders of magnitude faster with global dissemination into an easily comprehended display format. The technical evolution of computers, communications,

and sensors will make it possible to provide a continuous, near-real-time picture of the battlespace to war fighters and commanders at all levels. This situational awareness capability is truly the key to achieve information dominance in 2025.

Notes

1. Adm Jeremy M. Boorda, "Leading the Revolution in C^4I," *Joint Force Quarterly*, no. 9 (Autumn 1995): 17.

2. Col John Boyd (Ret.), "Observe-Orient-Decide-Act (OODA) Loop," address to the 2025 participants, Air University, Maxwell AFB, Ala., October 1995.

3. Capt Edward Swedberg, Chief LANDSAT System Utility Branch, interview with Major Adair SAFSP/ DLPO, Washington, D.C.

4. Ibid.

5. Ibid.

6. Maj Joseph Crownover, Air Force TENCAP Project Officer, interview with Major Adair, HQ USAF/XORR, Washington, D.C.

7. Dr Charles L. Morefield, "Situational Awareness in the 21st Century," USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the information applications volume, 15 December 1995), 25.

8. Col Gary Armistead, Surveillance and Reconnaissance Requirements Division, interview with Major Adair, HQ USAF/XORR, Washington, D.C.

Chapter 4

Concept of Operations

Imagine looking down at the earth from a position in space. You are far enough away that the earth appears as a small sphere and other planets can be seen in the distance. You distinguish movement and notice that it is the earth rotating about its axis and the moon revolving around the earth. Instantly, you realize that this is not a static picture display, but a very dynamic three-dimensional, computer-generated model with a simple control box in front of you.

Glancing at the control box. you notice a "Zoom" function and decide to explore the zoom-in feature of the system. As the earth gets larger, little mechanical bodies of various sizes and shapes surrounding the earth begin to appear. These objects are quickly identified as satellites; however, there are so many that the image of them appears blurred. Fortunately, the system has an isolation feature that allows the viewing of these satellites either one at a time or in any combination desired. The operator simply chooses which satellites to display and which to temporarily mask. Once the satellite(s) of interest is identified, a window appears on the display containing detailed information on that satellite or satellite system. A wealth of information is instantly available at a glance (e.g., origin, purpose, capabilities, orbital parameters). To facilitate understanding and

comprehension, the information is conveyed visually whenever possible. This allows the user to quickly comprehend and easily understand at a glance what may previously have been considered too complex or time-consuming to trouble with.

For example, after a particular satellite or satellite system is isolated, a time control feature is used to enhance understanding of complex orbital parameters and mechanics. In the real-time position, the display indicates the particular position of the satellite at that particular moment. Adjusting the time control forward or backward will display the satellite's position at any particular time, either past or future. Employing a compressed time mode (one second equals five minutes) creates a dynamic display of the satellites orbital parameters. Visually cueing on the satellite's motion around the earth quickly conveys an understanding of the orbital parameters to the user. Rotating the user's perceptive view of the earth (e.g., looking down on Korea versus the Middle East versus South America), or even displaying the view from the satellite as if the user were on board and dynamically viewing the earth below, are software features which further the user's understanding of the satellite system parameters.

Using these features, a user could examine various satellite systems at a glance and immediately discern crucial information: Where satellites are now and where they will be at a particular time, what their fields of regard[1] and fields of view are, any coverage gaps to exploit, what their function is, how and to what their data is linked, how to minimize the utility of others while maximizing yours, and much more. These questions merely scratch the surface of the amount of information available through a top-level examination of a satellite system. The real advantage is in the integration of available

information and the dynamic three-dimensional display which quickly and easily conveys information to the user.

Taking this another step, imagine that the display system or receive terminal is as compact as a lap top and that the information source feeding it is available anywhere, anytime. Furthermore, imagine that the information source is a "smart" source that it identifies the user connected and knows what information is required, and that it even knows the priority. This "smart" source, or intelligent processing node, would search existing databases and sources for information, automatically integrate an information package for the user, and forward tasking requests to assets for additional data when only insufficient data is available. If the intelligent processor required additional information, but determined that the existing information was useful to the user, the user would receive a preliminary information package and near-real-time feedback on the status of the final package. For example, this feedback would identify which data were insufficient to complete the request and/or indicate any forwarded tasking requests, along with the status of those tasking requests. The tasking status report would identify which assets were tasked, the priority evoked, and when (if at all) the user can expect completion and receipt of an updated information package. This would allow a decision maker to employ other assets to augment any expected shortfalls and/or explore alternative options. The data shortfall, for example, may generate a Unmanned Aerial Vehicle (UAV) sortie or require the launch of specialized microsat to supplement existing data sources.

Information on space systems is only the beginning. Zooming in closer, about a few hundred kilometers, most of the satellites disappear behind the display and the few low

flyers that remain are suppressed by use of the masking function. At a few hundred kilometers the full view of the earth is lost and the image rotating function is used to rotate the earth below us and change the perspective view of the display. The earth is rotated until the United States is centered in view below. At this distance, you cannot see coast-to-coast, but most of the 48 CONUS states are in view. Zooming in further fills our display with a 30-meter resolution true-color image of the ground below. The displayed picture is a composite of broad area images from a "LANDSAT/SPOT-like" system that has been geo-rectified and automatically correlated to the correct position on the earth. All this is transparent to most users who simply see 30-meter resolution true-color images. Topography such as rivers, mountains, plains, major roads, rail lines, and so forth, are clearly visible and easily distinguished.

Now let's say the user adjusts his controls to display terrain categorization and/or trafficability maps of the area below. The "smart" source would sense the request and integrate multispectral and digital elevation data under user-specified criteria from various systems/databases. This integrated product package is immediately available to the user's terminal.

The integration function, depicted in figure 8, is completely transparent to the user unless certain required data are unavailable to the "smart" source. In this instance, the user is made aware and is provided status through the feedback report mentioned earlier. The user could even request historical data from any open terminal which would prompt additional integration and data searches by the "smart" source. For example, the user may wish to display the various flood stages of the Mississippi River for locating new towns or potential crossing points. The "smart" source would perform a data search,

apply an automated change detection algorithm, and make the integrated information package, tailored to the user's request, available at the requesting node.

This kind of information has enormous utility to the military and civilian populations. The "smart" source will sense the user, determine the authorized classification level, and make only the appropriate information available. It will also determine the user's priority and process the request accordingly.

If more detail is required in a particular area, the user simply zooms in until the required resolution is displayed. Actually, the user is simply transitioning through various levels of imagery from multiple sources. The system has produced an integrated package of an area by overlaying georectified images with control/reference points and ensured the accuracy to a level commensurate with the user's needs and security classification. In other words, you start with a picture of the earth, zoom in on a continent, then a state, then a town, perhaps a building, and finally down to a small window of particular importance. The system simply transitions through various sources of imagery which is automatically integrated by the "smart" source and completely transparent to the user. Once again, if the data required to produce the requested integrated product are not immediately available, an automated tasking request is forwarded to collection assets, followed with a status report to the user.

The user is now interested in a different kind of information in a different part of the world. Let's zoom out from the building window for a moment to display an area about 1500 NM X 1500 NM. Now rotate the earth until Iraq is centered below. The user wishes to visualize the air picture over Iraq. This request is immediately sensed by the "smart" source, which begins to integrate the data from all sources and provide an

integrated information package based on the requested criteria from the user. Within seconds, an extremely cluttered and confusing gaggle of multicolored, multifigured, and mutiidentified icons appear overlaid on the image of Iraq. Tiny blue F-22 icons, blue C-17, UAV-3, TAV-2, E-5, and other coalition aircraft are smeared on top of yellow unidentified, white commercial, and red Iraqi aircraft. Since the user did not specify a time period to display, the system defaulted to the last 24 hours of reported activity in the region which virtually saturated the display with reports.

The user now specifies a request for more recent information, specifically the last 15 minutes of activity in the area. Within seconds, a much less cluttered display is observed and the user can quickly see the aircraft currently in the area and the flight paths linking associated aircraft. Some areas with multiple aircraft may still appear confusing, but zooming in on those particular areas quickly resolves any confusion. The user may also notice changes and additions as the system attempts to automatically update the display with the latest information available. At this point the user decides to overlay the latest threat (anti aircraft artillery (AAA), surface-to-air-missiles (SAM), radars) information. The display refreshes, and color-coded icons for target tracking, surveillance, and air traffic control radars, and other potential threats appear. The associated error ellipses for the threats are also available and can be displayed at the discretion of the user. Again, transparent to the user is the integration of data from multiple collection sources, which also contributes to the associated accuracy of the information displayed.

If the user desires, he/she can zoom in on a particular threat to whatever level of imagery is available. In some cases where data is limited, only the terrain around the threat may be immediately available. An information window is also available, indicating

known specifications on the threat along with the original source of information. The user can also zoom in on a particular aircraft to receive more detailed information. Similar information displays can be generated to provide situational awareness for the ground and naval forces also. Through use of the zoom feature, the field of view for situational awareness can be controlled to display the entire theater or any particular region of a theater. The particular theater or region of interest and display information are controlled by the user.

What the user has is an invaluable tool which can provide a global situational awareness of whatever the user specifies, and display the information in a three dimensional form that is quickly and easily understood at a glance. The fact that the display is small and portable so that the information is available anywhere at anytime adds to the tremendous utility of the system.

A subtle but extremely noteworthy and essential feature of the system is the capability to integrate information from IMINT, SIGINT, HUMINT, MASINT, surface, air, and space collection assets, as well as commercial and civilian data, to provide the highest fidelity product possible (fig. 3-5). Breaking through existing security, interoperability, and organizational barriers is the first challenge to total system effectiveness.

Notes

1. Field of regard refers to the area a satellite has coverage of; a satellite may have coverage from horizon to horizon, but may be able to see only a fraction of its coverage area at any given instant of time (field of view).

Chapter 5

Enabling Technologies

Implementing real-time space and reconnaissance information systems and the concept of a global grid of multiple intelligent plug-in nodes as a reality depends on a number of things, but in 2025 it will focus on the I^3S. The I^3S will be a virtual shopping center of information containing many different sources (stores), allowing each customer to "shop" the sources that will provide the needed information. To create the I^3S; to achieve the level of information demanded; and to develop the storage capacity, processing speed, and individual information analysis loops needed to support it will require significant leaps in technology in the next ten to fifteen years.

To achieve this goal, many factors must be considered. These include the availability of financial resources, the overall state of the world economy, differential rates of technological advancement, political leadership, decisions on the relative priorities on the national agenda, and the overall stability of the world scenario. While these factors make predicting future events and technological advance very difficult, some certainties do exist. Consumer technologies will achieve rapid and continuous progress because of the commercial incentives and private demand for advancement. Joint venture technologies, between the private and public sectors, may not achieve the same kind of advancement

due to the limited funding that the public sector can provide and the private sector's being unwilling to fund projects that will not return the profit margins expected by stockholders. Unlike the past, it is less and less likely that public funds will be used for purely military technologies. Consequently, in order to fund an information architecture that can function on demand to provide the kind of total capability needed in 2025, the public sector needs to establish a joint office to work with the private sector for developing and sharing the required technology.

This vision of the future, with "in-time" access to the information required, will be heavily dependent on quantum leaps in telecommunications, computer, and sensor capabilities. Many of the technologies needed for 2025 are in the minds--and on the drawing boards--of scientists today: total fiber networks; satellites operating in the 100 GHz range and above; terrestrial fiber links operating in the tera-bit range; computers using optics, DNA, or proteins instead of electrons; and cheaper, more articulate sensor systems hosted on space, airborne, and ground platforms.

Telecommunications

Requirements by the year 2025 for personal, business, and military communications will surpass anything thought of today. The globe will be a virtual network with near instant connectivity to almost any person, almost any place, as depicted earlier in figure 5. "Telecommuting, by 2025, will be telepresence--the ability to "be" where you really want to be and still operate in a very real way. Voice, video, data or any combination will be available in real time without distortion or sacrificing quality of one for the other."[1] Traditional narrowband (voice) and wideband (data) internetworking will be joined by a

new category, "broadband." "Broadband services are just being identified and understood, as we pursue applications such as videophone, high-definition TV, image transfer, and supercomputer-to-supercomputer connectivity. . ."[2] But clearly, this is the direction we must head to ensure availability of the wide bandwidth pipes required to transfer tomorrow's very high data rates. The Air Force and DOD must fully support and exploit this technology development which brings "in-time" information into the cockpits of aircraft, remote cockpits of UAVs, consoles of ships, dashboards of land vehicles, and troops on the ground, and then automatically updates the information in a moving digital situational awareness display.

Desert Shield/Storm stressed the military's current communications capability beyond its capacity, even with the use of all available commercial mobile terminals[3] and commercially procured circuits. These circuits provided connectivity for "common user" requirements as well as specialized data bases for the core automated maintenance system, the standard base supply system, and other "support-type" systems. Communications connectivity for these systems used large fixed and mobile satellite ground stations. From there, much of the data went through an analysis process before being forwarded to the pilot or soldier who needed it. This somewhat lengthy process was not totally responsive to the war fighter or his support elements.

These connectivity and analysis functions were not designed to provide in-time reconnaissance and surveillance data to individual aircraft or soldiers. The delays in relaying information to those who needed it were unacceptable. Capt Scott O'Grady's shootdown was an example of this phenomenon. Even though system assets had identified and reported the SA-6 threat prior to the actual shootdown, the in-theater assets

at the time could not pass this information to Captain O'Grady in time to affect a different outcome.[4] Improvements to support the war fighter are being made. The joint tactical information distribution system (JTIDS) and the multifunctional information system (MIDS), using the joint-service common datalink (link 16), will give individual pilots a "multisensor" picture of the battlefield by providing access to various sensor platforms.[5] However, with I^3S we see a capability far beyond that provided by link 16.

In order to support the "in-time" requirements of the future, technology will have to provide computers operating in the tera-bit range, communications paths with the wider bandwidths needed to support this computer power, smaller aircraft antennas, and pocket-sized transceivers. These systems, to be mounted in aircraft and ships and carried by soldiers on the ground, will be fundamental to passing the in-time information (to include data, imagery, targets, coordinates and, status) required by our various forces. As an example of the data capability to be required, passing ultra-high-definition TV pictures will require a data rate of 100 Mbps because of its high resolution.[6] Most users won't have a requirement for this level of detail, but it must be available for those that will. Communications networks will require "smart" automated management systems that can recognize their customers, perform security checks on authorized access levels, and know the nodes to connect to in order to retrieve the requested data--while at the same time, serving a multitude of other customers.

To satisfy the demand for information in the future, we will need seamless fusion and integration of broadband, multimedia networks for the movement of enormous amounts of information to our forces at very high data rates. Advances in data compression techniques will continue to steadily improve bandwidth efficiency.[7] Networks using

asynchronous transfer mode (ATM) technology are expected to be operating in the 2.5 Gbps range, or even higher in the future.[8] ATM builds a transport cell of a fixed size. These cells are made up of data and digitized video and voice information that is grouped together for transmission. Processing cells of a fixed size allows the network to operate at higher speeds and with greatly improved efficiency. Consider the standard lanes of a highway in a major metro area during rush hour. The lanes are packed with vehicles of various sizes, personal vehicles with one or more passengers, small and large commercial trucks, and motorcycles, all in stop-and-go traffic. Now, take the people out of the personal vehicles and put them into buses with access to the express lane. The buses are all the same size and can travel at a constant speed, in formation, to the destination. The trip now becomes much faster and more orderly.

Research advances have also been made in using optical technology for ultra-high-speed telecommunications called photonic fast packet switching. "Optical frequency carriers have an almost unlimited bandwidth potential to the 20 Tera-Hertz range!"[9] Commercial fiber optic cables currently pass data in the 2.5 Gbps range--capable of moving a copy of the *Encyclopedia Britannica* from coast-to-coast in a second's time.[10] This advancing technology will likely overcome a major stumbling block of current electrical interface switching—lack of high speed because of transmission path limitations. Current optical-electrical connections are also an impediment to very-high-speed networks as the data must be slowed to the rate acceptable at the electrical connection. A problem with creating an optical superhighway is multiplexing the data (allows for the transmission of many different users' data on a single path) and then moving it long distances without having to convert it back to an electrical signal for

amplification along the way. The recent development of the optical amplifier to restore the optical signal over long distances will eliminate this need for optical-electrical connections during transmission.[11] "Optical interconnects . . . consume significantly less electrical power . . . and can provide large numbers of interconnect channels in a small, low weight, rugged subsystem."[12] It is conceivable that an optical computer could be built through the use of photons instead of electrons.

Satellite systems will continue to play a key and increasing role as we move toward 2025. These systems will provide the primary connectivity to aircraft and will be the only method capable of passing the high data rates that many I^3S products will require. When the pilot wants to see an up-to-date situational map, a live video feed of his upcoming target area, or the latest BDA on his last target run, I^3S will generate it and a satellite downlink will deliver it. Satellite systems will also continue to meet the communications needs of customers on the ground and afloat, and on a much grander scale.

Advances in satellite technology are on going and will need to continue if we are to meet 2025 requirements. "Satellites of the future may operate in unconventional orbits, be very 'intelligent,' have enormous processing power, and require only supercompact and lightweight optics or electronics."[13] I^3S will require many, very small, inexpensive satellites. They will be the heart of our connectivity for airborne assets, deployed forces, and ships at sea where it is impossible or impractical to run fiber optic networks.

The iridium network of 66 small, low-earth orbiting (LEO) satellites, which is expected to be operational in 1998, will provide seamless handheld connectivity anywhere on the planet.[14] These satellites will be capable of passing voice, data, and facsimile transmissions through a pocket-sized transceiver.

In addition to the iridium network, direct broadcast satellites (DBS) have bandwidths of 1 Gbps or more. DBS systems are currently being sold to private users for home reception of television programming normally found on cable TV systems. DoD is developing its version of DBS, to be called the joint broadcast system (JBS). Both DBS and JBS operate in a "receive" mode whereby one (or possibly a few) ground station transmits information to the satellite which then resends it to many receivers. The very high bandwidth of these systems will significantly reduce transmission time of critical data. To put this in perspective, an air tasking order (ATO) of 1.1 million bytes would take over an hour to transmit on a standard 2.4 kbps UHF circuit but only 0.38th of a second on a 23 Mbps JBS system! An annotated 8 X 10 imagery of 24 million bytes would take 22.2 hours at 2.4 kbps but only 8.4 seconds on JBS. The complete Desert Storm log support Time-phased force and deployment data (TPFDD) (250 million bytes) would take 9.65 days to transmit at 2.4 kbps but only 1.45 minutes on JBS.[15] This is the magnitude of the quantum leap in transmission capability required to ensure that all forms of "in-time" information can get to where it is needed, when it is needed. The Air Force, as the executive agent for JBS, will play the leadership role in bringing this technology to DoD. The next generation of JBS, and the one that I^3S will need by 2025, must have full two-way (send/receive) transmission capability from one user to another anywhere in the world, and it must be capable of serving many users simultaneously.

Computers

Similar advancements are being made in the arena of computing power. The 1975 Apple-1 computer had the same computing power as the 1960 IBM-7090 mainframe costing $5M. A Pentium computer that cost $5K in 1994 had the computing power of a near priceless 1975 Cray-1 Supercomputer. Analysts predict that in the next few months, INTEL will reduce the price of one of its Pentium microprocessor chip lines by 65 percent.[16] This trend is expected to continue with available computing power doubling every 18 - 24 months (as it has for the last three decades) and chip prices continuing to fall. According to David A. Patterson, a professor of Computer Science at the University of California, Berkley, on-chip memory capacity has grown by a factor of four every three years, but memory speed has not kept pace-- and the gap keeps widening.[17] In the **New World Vistas** "Information Applications Panel" volume, Drs. Harold W. Sorenson and Ronald D. Haggerty are of the opinion that memory and storage devices are keeping pace with chip development.[18] Regardless of this difference of thought, advances are being made in memory technology--and these advances must continue if we are to meet the challenges of faster computers and broadband data networks. For the future, Mr Patterson proposes that processors and memory be merged on the same chip to keep processor speed and memory capacity at the same rate of development.[19]

A current capability we lack because of the computer and sensor technology required is the ability to fingerprint a specific item, whether it be tank, truck, or aircraft, and then, based on that fingerprint, know at any given instant where that item is. This concept would identify enemy resources with a laser imprint that can later be detected by sensor systems, similar to a vehicle identification number. This capability would have

brought welcomed relief in Desert Storm as we tried to locate SCUD launchers before they had a chance to fire their rockets. The fingerprinting technology is being researched and will be discussed in the sensor section. The computing power required to keep track of all this information is massive—but the requisite technology is on the way. "At that rate (of microprocessor development), a factor of 1,000 increase in rate would only take about 20 years, so that a capability to detect and track trucks, tanks, and planes from space could become available as early as 2015."[20] Therefore, an important part of the information to be available in I^3S is already envisioned to occur ten years before 2025.

"The Advanced Research Projects Agency (ARPA) is sponsoring the development of a massive parallel computer capable of operating at a rate of one trillion floating point operations per second (1 tera FLOPS)."[21] Improvements in data storage and retrieval will come from "advances in . . . such media as holography and optical storage . . . an optical tape recorder capable of recording and storing more than a terabyte of data on a single reel is being explored . . . vertical line block (VBL) chips could achieve (volumetric) storage densities ranging from one gigabit to one terabit per cubic centimeter. Chip data rates, a function of chip architecture, can range from one megabit/second to 100 megabits/second."[22] This increase will enable creation of an archival database to store the vast amounts of raw data required by the I^3S to support users.

A number of new computing concepts are on the horizon. In an article in *Science* magazine, James Glanz outlines five developing technologies.[23]

1. *Quantum dots* which trap individual electrons in semiconductor material so small that the electron wave in the dot is driven to take on a specific energy state.

Processing speed increases on the order of 100 to 10,000 are anticipated, but current developments require stabilized low temperatures in which to operate.

2. *Quantum computer technology* is based on the belief that the wave of a single electron has the capability to take on many different states at once. The individual states hold a specific piece of data and could be run concurrently on a parallel processor. Speed increases of a trillion or more show up in the most optimistic theories. These computers are only anticipated to be able to solve problems dealing with exponential accumulation of error-type problems.

3. Holographic Association works on a *nonlinear process* that allows "information in one light beam to affect how the material 'processes' a second beam. In effect, the medium performs many computations in parallel."[24] Speed increases on the order of 100,000 may be available. This process will likely find a home in pattern recognition and artificial intelligence, two of the things that our I^3S processor will have to master.

4. *Optical computers* will process via light instead of electrons. Processing by using pulses of light, rather than electrons, can significantly increase speed. Basic speed increases may be as high as 100,000, and could be further increased with additional parallel processing. Other optical components will also have to be developed or improved to enable this technology.

5. *DNA computers* will use "up to 2^{70} DNA molecules. . .[to] act as individual processors."[25] DNA processing, if perfected, will allow the capability of processing billions of operations simultaneously.[26] Richard Lipton, a Princeton computer scientist, has developed a DNA algorithm for cracking the digital

encryption standard.[27] Although it is currently a lengthy process, it shows the significant processing power anticipated in computers of the future. Speed increases of a trillion are being talked about, but this technology is in its infancy. It appears the computer and connectivity capabilities that I^3S will require will be there. We need to come to grips on how to harness them to best meet our military requirements.

Virtual reality will use the power of these advanced computers to generate artificial situations that can be explored, "touched," and modified. DOD plans to have a working holodeck[28] by the year 2020. These artificial environments will feature all of the human senses allowing the user to become immersed in the scenario. Improvements in this technology will be incremental as we provide high-resolution synthetic environments from virtually any place.[29] "The important thing about virtual reality is . . . [that] it permits people to behave as if they were someplace they are not."[30] United States Special Operations Forces will be able to use this technology to quickly and accurately assemble a computer mock-up of any area in the world where they may have to make a forced entry or rescue mission.[31] The Air Force will likely train pilots in a 3-D virtual reality simulator, complete with audio that mimics their current surroundings.[32] There is probably no better way to train than with a realistic view of the current situation. Imagine, through the use of advanced group software technologies and virtual reality, a "'virtual Pentagon' a destination in cyberspace accessible by Air Force personnel from wherever they happen to be on the planet."[33]

Neural networks in the computers of 2025 will accurately mimic many of the human brain's processing capabilities. Expert systems will use human knowledge embedded in a computer to solve problems usually thought to need human intervention.[34]

Together, these capabilities will allow computers to fuse the vast amounts of data required to provide, at a moments notice, the specific information required by a joint forces air component commander (JFACC), other military fighter or a commercial customer. Neural networks must overcome the computer's current limitations in speech and feature recognition, interpreting trends, and learning from experience.

Telepresence models will allow humans to perform functions from remote locations as if they were at the location of the function being performed. For instance, telepresence models will allow for "remote surgery. . . giving the surgeon consistent, natural, sensory-rich accessibility. Manipulation of micron-sized objects with synthetic haptic[35] feedback" will make this possible.[36]

Intelligent software agents, once developed, will greatly aid this process. "An "intelligent agent" is a robust software program that communicates with other entities to gather information and make decisions."[37] Agent programs will have a sense of themselves as independent entities. An ideal agent will know its goal and will work diligently to accomplish it. Some of the tasks intelligent agents will be able to perform include deciding where to acquire requested information from I^3S, working with other nodes to solve complex problems, performing the fusion function for the vast amounts of data in I^3S, and protecting the I^3S resources from unauthorized intrusions. *New World Vistas* "Information Technology" volume lists five motivators for using intelligent software agents:[38]

1. The quantity of information [in 2025] will be too vast and its quality too uneven for most humans to suffer through.
2. Data and database [proliferation will] demand a variety of translators.

3. Stored media will have increasing dimensionality in a variety of formats.
4. The need for improved human—computer interaction.

Sensors

Sensor technology will grow at the same pace as computer technology and will be highly dependent upon it. New combinations of sensors, including those mating optical and radio frequency (RF) bands and others that use data from a large number of spectral bands, are the trends of the future.[39] Smaller reconnaissance satellites will provide more real-time broad-area coverage with extremely high resolution. Downlink bandwidths will be expanded to support increasing in-time capability and requirements. Various countries will likely join together to build new satellite sensor systems, reducing costs, to each, providing an expanded capability, and sharing the intelligence. According to former US Air Force Secretary Edward C. Aldridge, Jr., "The goal is to coordinate international military/civilian space assets to provide a real-time 'global awareness' of crisis areas."[40]

In 2025 you may likely find long-dwell imagers (LDI) replacing our periodic aircraft or low earth orbiting systems. Existing constellations of specialized microsats, or fleets of on-demand microsats which can be injected into orbit as requirements or situations dictate, are part of normal operations in 2025.

Other examples of futuristic sensor system technologies include, but are not limited to these four:

1. A capability to build moving devices onto microchips.[41] This microelectromechanical system (MEMS) chip will combine mechanical functions with electrical functions.[42] This moving mechanism may become an optical mirror,

such as that employed in Fourier Transform Spectrometers. These spectrometers yield high-resolution wavelength discrimination (hyper-spectral) sensors that not only look at factories/refineries and measure activity, but also spectrally resolve what is being manufactured and the origin of the raw materials.

2. High-resolution, day/night, all-weather imagery will be provided by clusters of microsats acting as a synthetic antenna for millimeter, radar-like, resolution. Through real-time processing of the phased history data from multiple clusters, 3-D imagery will be routinely available while small, visual 3-D displays will become commonplace in the field at all levels of service.

3. Collecting and processing the radiation wave fronts from "EMP-like" generators focused on buildings, hangars, or other structures, provides a giant x-ray effect for locating insurgent/terrorist groups or blueprinting structures for potential targeting. This could even be used in the civil sector to x-ray buildings and bridges to determine whether or not they are structurally sound or identify weaknesses following natural disasters. This information could also be exploited by the military against enemy structures.

4. ELINT will routinely provide 24-hour surveillance of threats as well as blue forces. When interrogated with a special code, a chip embedded on our forces will transmit a low probability of intercept (LPI) signal not only providing their GPS coordinates but also a mini-status report. This mini-status report may contain human vital signs, how much fuel is in a vehicle, the amount of ammunition remaining, and so forth. This kind of information overlaid with current imagery and OP-ELINT information will be available directly into the cockpit for pilots,

remote cockpits of UAV drivers, consoles of ships, dashboards of land vehicles, and automatically updated in a moving digital situational awareness display.

The Air Force publication, *New World Vistas: Air and Space Power for the 21st Century,* "Sensors Volume," also outlines seven illustrative sensor system concepts of things we can expect in the future.[43]

1. *Target reporter* that will provide persistent battlefield surveillance using a long-endurance UAV. A concept for an over-the-water, ultra-endurance UAV is found in Air Force Project 2025 Concept Number 900438, ultra-endurance high-altitude ocean loitering uninhabited reconnaissance vehicle.

2. *Integrated arrays of distributed unattended ground sensors* that will use small devices equipped with multiple microsensors to monitor ground activity and relay information to overhead platforms.

3. *Underground target surveillance* to monitor underground activities dealing with NBC weapons, leadership hubs, etc.

4. *All-condition concealed target detection,* having the ability to detect targets in camouflage and foliage will exploit many sensors.

5. *Weather surveillance and prediction* will make broad-area and local military-unique weather available to war fighters. See the Air Force 2025 White Paper, "Weather Modifications," for more information on future weather capabilities. Also, Air Force Project 2025 Concept number 900502 proposes putting meteorological sensors on aircraft for continuous real-time data.

6. *Modular, integrated, multifunction phased array-based electro-optical system* will provide multiaperature defensive and offensive operations processing.

7. *Low-cost space-based surveillance* will be orbited on small, launch-on-demand satellites. This concept is a main theme for the success of I^3S. Air Force 2025 project number 900518 proposes electronic grid throwaway sensors to provide small, economical, disposable sensors that the Air Force could use to seed the battle area for reconnaissance.

More information on these future sensor concepts can be found in the **New World Vistas**, "Sensors" volume. It also outlines seven representative operational tasks and the required enabling technologies for future sensors.

Notes

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2. Robert K. Heldman, *Future Telecommunications: Information Applications, Services, and Infrastructure* (New York: McGraw-Hill, 1993), 153.
3. Capt Dave McKenzie, "Comfy Storm Communications," in *The Desert Shield, Desert Storm Comm Story*, ed. Col Randy Witt (Riyadh, Saudi Arabia: Headquarters USAF Central Command Air Forces, March 1991), 72.
4. Col Gary Armistead, Surveillance and Reconnaissance Requirements Division, interview with Major Adair, HQ USAF/XORR, Washington D.C..
5. Edward J. Walsh, "An Emphasis on Core Competencies," *SeaPower*. (April 1995) 43–50.
6. Smubhash Nigam, "ISDN and ATM: The Odd Couple," *Telephony* (4 September 1995), 26.
7. *New World Vistas,* (unpublished draft, the information technology volume), 16.
8. Nigam, 26.
9. Ibid., 26.
10. Vincent W.S. Chan, "All-Optical Networks," *Scientific American*, September 1995, 56.
11. Ibid., 56.
12. "Leveraging the Infosphere: Surveillance and Reconnaissance in 2020," *SPACECAST 2020 Report* (Maxwell AFB, Ala.: Air University [Draft], B-20.

13. Joseph N. Pelton, "New Satellite Designs: Leosats to Spidersats," *Satellite Communications*, September 1991.

14. Robert W. Kinzie, "Welcome to IRIDIUM TODAY," *IRIDIUM TODAY* 1, no. 1 (Fall 1994): 3.

15. Maj Steve Spano, "Information Warfare," address at the Air Command and Staff College, Maxwell AFB, Ala., January 1996.

16. Bill Husted, "How Low Can They Go? Steep Cuts in the Cost of PCs by Year-end," *Atlanta Journal-Constitution*, 2 February 1995, F-1.

17. David A. Patterson, "Microprocessors in 2020," *Scientific American*, (September 1995), 49.

18. Harold W. Sorenson and Ronald C. Hagerty, "Coordinating, Planning, and Execution in an Information Rich World," *New World Vistas,* (unpublished draft, the information applications volume), 67.

19. Patterson, 50.

20. "LEVERAGING THE INFOSPHERE, Surveillance and Reconnaissance in 2020," B-5.

21. Ibid., B-20.

22. Ibid.

23. James Glanz, "Computer Scientists Rethink Their Discipline's Foundations," *Science Magazine*, 8 September 1995, 1363.

24. Ibid.

25. Ibid.

26. Robert Pool, "A Boom in Plans for DNA Computing," *Science Magazine*, 28 April 1995, 498.

27. Ibid., 499.

28. Holodeck is a term extracted from the TV Star Trek series referring to a computer generated virtual reality room which allows one to experience the sense of being in any environment, limited only by their imagination.

29. *New World Vistas,* (unpublished draft, the information technology volume), 37.

30. Brenda Laurel, "Virtual Reality," *Scientific American*, September 1995, 70.

31. James Kitfield, "Trading Bullets for Bytes," *Government Executive*, June 1994, 18.

32. Laurel, 70.

33. *New World Vistas,* (unpublished draft, the information technology volume), 101.

34. "Artificial Intelligence and Expert Systems Technology," National Defense University, Information Resources Management College, Emerging Technologies Course, 1994.

35. Haptic is defined as "of or relating to the sense of touch" in the American Heritage Dictionary, 2d College Edition.

36. *New World Vistas,* (unpublished draft, the information technology volume), 37.

37. Sorenson and Hagerty, 76.

38. *New World Vistas,* (unpublished draft, the information technology volume), 39.

39. *New World Vistas,* (unpublished draft, the sensors volume), vi.

40. Craig Covault, "Cooperative Recon Gains Momentum," *Aviation Week & Space Technology*, 9 October 1995, 28.

41 Andrew C. Braunberg and Robert K. Ackerman., "Advanced Research Projects Agency Emphasizes Rapid Development, Use," *Signal Magazine*, December 1995, 21.

42 *New World Vistas,* (unpublished draft, the information technology volume), 24.

43 *New World Vistas,* (unpublished draft, the sensors volume), xiii.

Chapter 6

Threats and Countermeasures

Information warfare is defined as any action taken to deny, exploit, corrupt, or destroy the enemy's information and its functions; protecting ourselves against those actions; and exploiting our own military information functions.[1]

The threats to our telecommunications, I^3S, processors, and sensor systems will only increase as we approach 2025. As technology grows, so does the enemies', terrorists', and computer hackers' ability to invent ways to damage, corrupt, or destroy these systems. The Air Force must ensure that it stays at least one step ahead of these threats. The use of closed systems or those that have a very high degree of protection through the use of cryptographic and to-be-invented security algorithms will be a must. Unbreakable encryption codes will exist as standards throughout the world and will help in this effort.[2] The Air Force's information warfare program will be a key to this success. The Air Force pamphlet "Cornerstones of Information Warfare" lists the activities that comprise information warfare:

1. Psychological Operations—using information to affect the enemy's reasoning.

2. Electronic Warfare—denying accurate information to the enemy [jamming, enemy OPSEC].

3. Military Deception—misleading the enemy about our capabilities or intentions.

4. Physical Destruction—physical attack ranging from conventional bombs to electromagnetic pulse weapons.

5. Security Measures—keeping the enemy from learning about our military capabilities and intentions [and the what, where, why, and how of our C4I operations].

6. Information Attack—directly corrupting the enemy's information without visibly changing the physical entity within which it resides.

These are also the threats to our systems. We can be sure that our enemies are aware of these types of activities and will try to penetrate our systems while protecting theirs by using them. The Air Force will not be alone in this battle. Many of the companies providing leased commercial service the to Air Force will also be vulnerable. We should work with them to develop security measures that will protect our interests. Perhaps the most powerful fix to these problems is flexibility, with the capability to quickly disseminate a change to the systems software.[3]

Security

Security will focus on protecting I^3S resources (telecommunications, processors, and sensors) and the access to them. Fail-safe technologies will be established for entering and querying the network. Pilots will be able to press their finger against a visual display screen in the cockpit to sign-on to the I^3S network. They will have access to any required information, at authorized security levels, for the duration of that mission. The fingerprint impression on the display will initiate sign-on, enable security checks, and verify any other security details. This technology, known as biometric identification, will provide

identifications by means of "physiological traits such as face recognition, finger-, retina-, or voice-print."[4] Similar systems will be used at ground facilities around the world.

Countermeasures

Countermeasures for deception, intrusion, piracy, and electronic warfare will be critical to ensure the integrity of the information gathered, stored, and provided.

> Active and passive systems can overcome jamming, ground station attack, and enemy OPSEC. In the case of jamming, frequency hopping and "hardening" of space links are both effective countering techniques. Hopping rates currently exceed 3,000 hops per second. These rates will most likely continue to increase exponentially in the future, which could make many forms of jamming a minor irritant.[5]

Ground station attack can be prevented by picking locations that offer the most security. For instance, by 2025, Cheyenne Mountain Air Force Base (CMAFB) will be a great place to install the primary I^3S. Reductions in processor size will significantly shrink the current floor-space requirements of today's installed systems, freeing up more than enough room for I^3S. Other secure sites, although probably not as secure as CMAFB, should be developed from currently existing Air Force properties for other I^3S installations. Protection for sensor and communications satellites can best be ensured through redundancy, using smaller and much less expensive platforms and payloads. There exists a need to achieve a point where it is cheaper to build and launch these systems than it is for the enemy to take them out. The LEOs and microsats discussed earlier are the first step in this direction of small, relatively inexpensive satellites. Security in 2025 will be, as it is today, everyone's business.

1. Department of the Air Force, *Cornerstones of Information Warfare* (Washington, D.C.: Department of the Air Force), 3.

2. USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the information technology volume, 15 December 1995), 21.

3. Ibid., 74.

4. Ibid., 94.

5. "Leveraging the Infosphere: Surveillance and Reconnaissance in 2020," B-18.

Chapter 7

Conclusions/Recommendations

By 2025, telecommunication and dissemination techniques, software technologies, computing power, computer-to-computer interfaces, data compression standards, fuzzy logic, intelligent systems, new dissemination practices, system networks, and human-computer interfaces will be changed in ways that can only be imagined today. These rapidly and continuously advancing technologies will fuel the I^3S.

The goal of the I^3S is to create a seamless end-to-end process where dynamic interfaces coexist between and among mission planners, collection resources, producers, users, experts, databases, and weapon platforms. This vision calls for a virtual reality environment where decision makers, war fighters, peacekeepers, policymakers, and/or law enforcers, are connected with tailored, insightful, and actionable intelligence when they need it, where they need it, and how they need it. The intent is to empower participants to push and/or pull data to effect the overall collection, processing, analysis, and dissemination process.

To make this a reality, a broad global network of multilevel connectivities is absolutely critical. The network must connect the proper intelligent nodes with the most experienced and/or knowledgeable people to provide the tools with which to share ideas,

discuss options, brainstorm alternatives, or simply acquire the necessary information in time to be useful.

The key objective is to reduce fog and limit friction for friendly forces while increasing fog and friction for opponents. Sharing knowledge, instincts, and experience will be the ultimate force multiplier as well as the ultimate challenge. Building a sense of "community" to truly obtain top-sight vision will undoubtedly fuel success in achieving information dominance. Success in this area will truly be *revolutionary*.

Considering the increased pace and level of new technological developments, the computing speed and bandwidths required to achieve this top-sight vision are expected to be available by 2025.[1] Meanwhile, budget reductions in the DOD will fuel the continuing shift of new technological development to the commercial sector. Therefore, streamlining and redesigning interfaces across military and civilian sectors will not only drive down overall costs, but will ensure that the DOD remains a key driver in the research and development process.

Taking advantage of commercial opportunities and capabilities will further reduce government research and development costs, thereby freeing financial resources to fund operational security needs and costs for employing and deploying the I^3S. To ensure optimization and maximize utilization of the I^3S, a significant paradigm shift in organizational cultures and partnerships must occur.

The shift must knock down stovepipes within and across commercial, government, and military sectors, transforming archaic command and control vertical structures into new lateral and integrated partnerships. "Best practice" ideas and concepts must be

afforded analytic review rather than allowed to become victims of "not invented here" mentalities.

Since cultural change is slow to evolve, the challenge for achieving information dominance must begin today. Accomplishing this monumental task calls for new leadership practices, modern management techniques, and improved education in how organizations and people cooperate, interact, and function. Success in 2025, whether dealing with international trade issues, international crime, terrorism, rouge states, committing forces to a battlefield, or expanding democracy, depends on those who dare to be bold today.

As outlined in this white paper, a number of technologies show promise in meeting the system requirements to make the I^3S a reality by 2025. Sophisticated enabling technologies will serve to coordinate the vast network of global collection and information assets to deliver the integrated information to the right machine, warrior, weapon, and person in time to be actionable. However, the combination of the I^3S network and the top-sight vision model[2] of human and machine interface, integrating across key pillars of political, economic, military, and information resources, will provide the most profound insight.

Achieving such high levels of cooperation will call for courageous leadership, perseverance, and focused vision coupled with the skill to balance new technologies and cultural change in education. Cultural change will prove to be the most difficult challenge. As a result, the degree to which leaders and organizations fail to achieve horizontal integration and cooperation across various structures will be directly reflected in the level of information dominance that is achieved in the year 2025.

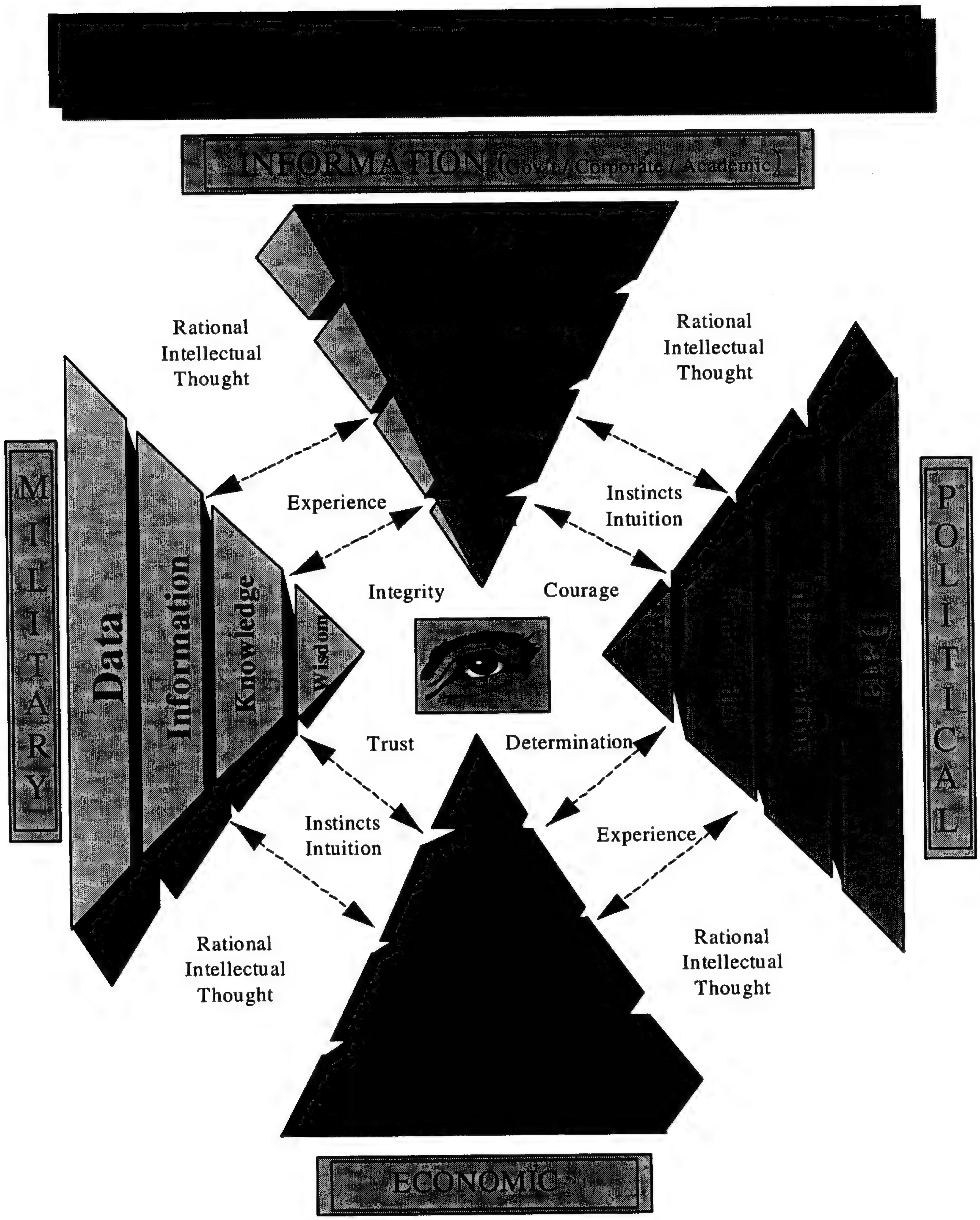
As participants converge, cooperate, and focus on the end result, true information dominance will accelerate. Too much attention on "cool" technologies at the expense of new cooperative and interactive business practices will result in a less than satisfactory endstate.

Whether the user is a warrior or a cabinet-level decision maker, the global I^3S incorporate the key concepts of the top-sight vision model to provide information, knowledge, insight, and wisdom to make success a consistent companion at all levels. The benefits to be realized from this approach are tremendous and will clearly assist America's military, political, social, and economic superpower status well beyond 2025. Conversely, the consequences of the status quo are just as significant, but far more dangerous. Change, therefore, must begin *now*!

Notes

1. Meeting with **2025** Assessors, Air University, Maxwell AFB, Ala., 26 March 1996.
2. Created by the Authors, Illustrated in Appendix A.

Appendix A



INFORMATION (Gov't / Corporate / Academic)
MILITARY
Data
Information
Knowledge
Wisdom
POLITICAL
ECONOMIC
Rational Intellectual Thought
Rational Intellectual Thought
Experience
Instincts Intuition
Integrity
Courage
Trust
Determination
Instincts Intuition
Experience
Rational Intellectual Thought
Rational Intellectual Thought

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